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Renewable Energy, Photovoltaic Systems Near Airfields: Electromagnetic Interference

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Recent increases in photovoltaic systems on Department of the Navy (DON) land and potential siting near airfields prompted this assessment of the impact of electromagnetic interference (EMI) from photovoltaic (PV) systems, on airfield electronic equipment. Existing literature is summarized, and tests to measure emissions and mitigation methods are discussed. The literature shows that the emissions from typical PV systems are low strength and unlikely to cause interference to most airfield electronic systems. With diligent procurement and siting of PV systems, including specifications for FCC Part 15 Class A compliant equipment and a 250-foot setback from communication equipment, little to no EMI impact on nearby communications or telemetry equipment is anticipated.

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EXECUTIVE SUMMARY

Recent increases in photovoltaic (PV) systems on Department of the Navy (DON) land and potential siting near airfields prompted Commander, Naval Installations Command to fund the Naval Facilities Engineering Command to evaluate the impact of electromagnetic interference (EMI) from PV systems on airfield electronic equipment. Naval Facilities Engineering and Expeditionary Warfare Center tasked Department of Energy National Renewable Energy laboratory (NREL) to conduct the assessment.

PV systems often include high-speed switching semiconductor circuits to convert the voltage produced by the PV arrays to the voltage needed by the end user. Switching circuits inherently produce electromagnetic radiation at harmonics of the switching frequency.

In this report, existing literature is summarized and tests to measure emissions and mitigation methods are discussed. The literature shows that the emissions from typical PV systems are low strength and unlikely to cause interference to most airfield electronic systems. With diligent procurement and siting of PV systems, including specifications for FCC Part 15 Class A compliant equipment and a 250-foot setback from communication equipment, NREL anticipates little to no EMI impact on nearby communications or telemetry equipment.

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INTRODUCTION

Directives to reduce the military's carbon footprint have led to an increased interest in photovoltaic (PV) systems deployed on military installations in the U.S. Sites near airfields are proving to be suitable for the deployment of PV systems, in addition to the customary locations on buildings and in open areas. However, specific considerations must be taken when deploying PV near sensitive communications or navigation equipment that is typically found near civilian and military airfields.

Recent publications have provided guidelines for locating PV systems near civilian or military airfields. The main siting challenges relate to glint and glare that can occur from PV modules when the sun is at a high incidence angle, as well as observing keep-away zones on approach paths. Excellent summaries detailing the challenge of deploying PV near airports include the FAA's *2010 Solar Guide* [FAA, 2010] and other summaries such as [Barrett, 2011] and [Kandt, 2014]. Specific guidance on glint and glare can also be found on Sandia National Laboratory's website at www.sandia.gov/glare.

This white paper addresses one aspect of PV interaction that is underserved in the literature—electromagnetic interference (EMI). Typically, this phrase is taken to mean radio frequency (RF) emissions, emanating from PV systems, that are impacting nearby radio receivers. This can also include any blocking or attenuation of nearby radar or communications by the PV system. Although the risk of EMI from PV systems is typically very low, it does merit evaluation in order to improve the confidence of site owners and other stakeholders.

Several case studies have indicated that EMI from PV installations are low risk. For instance, the FAA *Solar Guide* states that:

> *"Due to their low profiles, solar PV systems typically represent little risk of interfering with radar transmissions. In addition, solar panels do not emit electromagnetic waves over distances that could interfere with radar signal transmissions. Any electrical facilities that do carry concentrated current are buried beneath the ground and away from any signal transmission."*

Also, a recent Air Force Tiger Team investigation into PV near airbases found the following:

> *"Prior research and field investigations of electromagnetic emission (EME) from Solar PV arrays concluded that they produce extremely low frequency EME similar to electrical appliances and wiring. At a distance of 150 feet from the inverters, these fields dropped back to very low levels of 0.5 mG or less, and in many cases to much less than background levels (<0.2 mG).*
> *When considering sites for a PV array in close proximity to airfield instruments, the tolerance of the equipment to EME should be considered. If of concern, the methodology*

developed by the Air Force Research Lab for the ACC study can be applied in an engineering evaluation to validate a no-impact determination." [1]

TYPICAL PV EMISSION LEVELS

The Federal Communications Commission (FCC) CFR Title 47, Part 15 regulates RF emissions from commercial products. Compliance with Part 15 is not a requirement for large-scale power generation equipment, but many PV inverter manufacturers do qualify their residential or utility-scale equipment to this standard and it is easily validated when procuring equipment.

The FCC limits specify an upper bound on the amount of radiated emission that can be tolerated for a listed product. In practice, the amount of actual radiation from PV systems is typically so small as to be immeasurable above background RF noise. Multiple investigations into the topic were unable to detect any radiated EMI [Bonn, 1997; Piazza 2004]. This is explained by the low switching frequency of the PV inverter relative to RF frequencies; fundamental switching frequencies in the inverter are approximately tens of kHz, with higher-order harmonics only up to ~10 MHz [Araneo 2009]. These long-wavelength modes do not effectively couple to the outside environment, thereby limiting the strength of any radiated emission. Additionally, proper enclosure grounding, filtering, and circuit layout further reduce conducted and radiated emission.

To illustrate the relative emissions for FCC-compliant equipment, the following plot shows field strength vs. distance for a transmitting cell phone, and the maximum output of a FCC-compliant inverter. Comparing the field strength of both devices, the maximum expected field strength for a compliant inverter at a distance of 100 feet is comparable to the field strength of a cell phone a mile away. This is likely to be indistinguishable from background noise.

[1] Extracted from the unpublished "Solar PV Compatibility Project Tiger Team Final Report," developed by a Tiger Team assembled by the Air Force Encroachment Management Working Group. NREL received a copy from Naval Facilities Engineering Command, Atlantic.

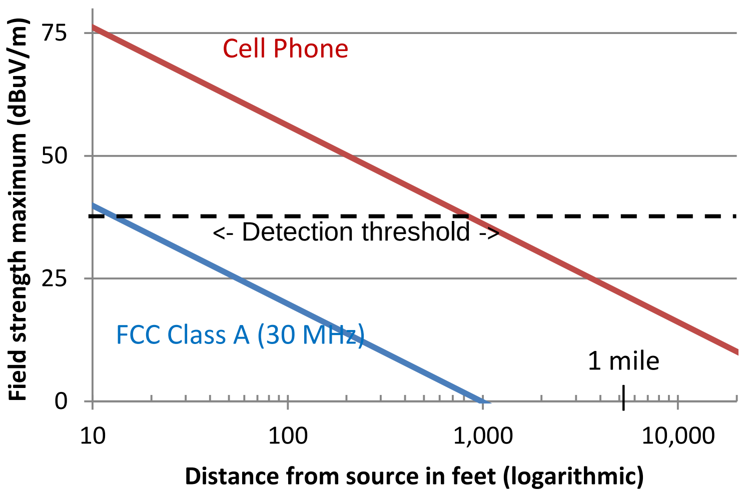

Figure 1: Measured transmit signal power (logarithmic dBuV/m) for a typical cell phone (red) and maximum allowed FCC class 'A' emission at 30 MHz.

Other pieces of PV systems equipment, such as step-up transformers, are not a source of EMI because of their low frequency (60 Hz) operation.

TYPICAL EMISSION SPECTRA AND COUNTERMEASURES

Compliance with FCC Part 15 radiated specification does not guarantee a lack of interference. Sensitive receivers operating below 30 MHz may be affected, e.g., AM radios. In particular, compatibility with nearby aeronautic navigation aids such as non-directional radio beacons (NDB) should be assessed. Plots of internal conducted emissions for commercial PV inverters (e.g., Araneo, 2009) show that internal frequencies attenuate rapidly at frequencies above 300 kHz. This suggests that any interaction between PV systems and nearby communications equipment is only likely to occur at frequencies below 1 MHz, if at all.

In the unlikely event of interactions with nearby receivers or transmitters in these low frequency ranges, options are available to address the interference. Although commercial inverters are equipped with inductor-capacitor (LC) filters that are optimized for system efficiency and cost, aftermarket LC filters can be installed to attenuate RF emissions at specific frequencies causing undesired interaction. Additional countermeasures may include enhanced equipment grounding of the PV modules, or specifying an inverter that solidly grounds negative PV conductors rather than leaving PV conductors ungrounded.

RADIATED MEASUREMENT TECHNIQUE

To conduct field measurements of radiated emission, a wide-band spectrum analyzer with sensitivity down to 150 kHz is required, along with an appropriate antenna. At high frequencies (> 1 GHz), a wideband antenna such as a bi-conical or log-periodic antenna has good response.

At frequencies below 30 MHz, the magnetic component of radiated emissions is typically monitored using a current clamp or loop magnetic antenna. The spectral signature of radiated emissions should be assessed both with the inverter turned off (background signature) and while operating at full power to determine the inverter's radiated emissions. A broadband increase in the level of RF emissions would indicate the presence of radiated emission from the inverter.

OTHER RF INTERACTIONS

At frequencies greater than 1 GHz, the impact of PV systems on communications is limited to the physical obstruction and reflection of these signals. This is particularly the case for collimated line-of-sight signals such as laser or infrared communications. PV systems are similar to other built structures such as buildings or sheds in that they are constructed of metal and glass, and they are non-transmitting. Similar consideration due to reflection and multipath should be given to PV systems, as well. In the FAA *Solar Guide*, several airport case studies indicate that setbacks of 250–500 feet were maintained between new PV systems and existing radar equipment. These setback values were sufficient to preclude impacts to the communication equipment. Similar modest exclusion zones should be considered for other critical telemetry or navigation equipment at civilian or military airfields.

SUMMARY

Photovoltaic inverters are inherently low-frequency devices that are not prone to radiating EMI. No interference is expected above 1 MHz because of the inverters' low-frequency operation. In addition, interaction at lower frequencies (100 kHz–1 MHz) is also very low risk because of the poor coupling of these extremely long wavelengths to free space, limiting propagation of the signal. In some cases where PV systems were deployed near existing radar equipment, a setback distance of 250–500 feet was implemented to minimize the physical blocking or reflection of the radar signals by the PV system. A similar 250-foot setback near any other critical communication equipment could be considered in order to attenuate any low-frequency emitted radiation that may be produced by the PV system.

With diligent procurement and siting of PV systems, including specifications for FCC Part 15 Class A compliant equipment and a 250-foot setback from communication equipment, NREL anticipates little to no EMI impact on nearby communications or telemetry equipment.

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